Available online at www.sciencedirect.com

ScienceDirect

Procedia CIRP 26 (2015) 683 – 688

www.elsevier.com/locate/procedia

12th Global Conference on Sustainable Manufacturing

A classification of remanufacturing networks in Europe and their influence on new entrants

Thomas Guidat[a], Mikko Uoti[b], Hannele Tonteri[b]*, Timo Määttä[b]

[a] *Institut für Werkzeugmaschinen und Fabrikbetrieb (IWF), Fachgebiet Montagetechnik und Fabrikbetrieb, Technische Universität Berlin, Germany*
[b] *VTT Technical Research Centre of Finland, Espoo, Finland*

* Corresponding author. Hannele Tonteri Tel.: +358-20-722-6843 ; fax: +358-20-722-7604. *E-mail address:* hannele.tonteri@vtt.fi

Abstract

In industrialized and emerging countries, remanufacturing is considered as a promising strategy to preserve growth and employment in a dematerialized economy. Successful remanufacturing is, regardless, limited to specific industrial sectors such as the automotive parts aftermarket. Transforming political ambitions to concrete implementation in industry cannot be done solely from a legal perspective. Objective of this paper is to enable potential new entrants to learn how the actors in remanufacturing value chains collaborate in networks. Authors led a survey among remanufacturing companies and identified three main network types regarding the degree of control from the Original Equipment Manufacturer over the remanufacturing process. Typical company profiles for every network type according to their specialization are defined. Objects and motives as well as the main challenges for companies which come through dematerialization are qualitative validated and discussed. An overview of future research axis for networking as a tool for expanding remanufacturing activities serves as a conclusion.

Peer-review under responsibility of Assembly Technology and Factory Management/Technische Universität Berlin.

Keywords: Remanufacturing; Remanufacturing networks; Dematerialization; Remanufacturing awareness; Market entry.

1. Introduction

Globally growing industrialization is extensively increasing the use of materials and increasing the concern about long-term potential of materials supply. Industrial firms are more worried about imminent material scarcity and dependence. At the same time the concerns about negative environmental effects and social as well as political tensions are emerging. For industrial firms the increasing resource scarcity and uncertainty eventually means increasing costs, calling for new operational concepts to improve dematerialization. Decreasing material usage and minimizing industrial waste would also improve the state of the natural environment.

Life-cycle thinking is crucial with circular economy. It means that the whole value chain of the product is taken into account, beginning from raw material extraction and conversion, and continued to manufacturing, distribution and use. The life-cycle ends with so called end-of-life stage, including re-use, remanufacturing, recycling, or energy recovery. The main aim of life-cycle thinking is to avoid burden shifting, minimizing the impacts at one stage of the life-cycle while helping to avoid increasing impacts elsewhere.

A recent report by Ellen MacArthur Foundation [1] reviews the potential of circular economy from a European viewpoint. By circular economy they mean "*an industrial system that is restorative or regenerative by intention and design*". Products are designed for a cycle of disassembly and reuse – waste does not exist. Circular economy is not based on consumption but on restorative use. Remanufacturing is one form of circular economy. The report estimates enormous potential for savings at the European level and new innovation potential to realize the circular economy.

In this paper the European remanufacturing industry is studied and the findings of the survey targeted at learning of the processes and networking practices of remanufacturers as well as the rationale behind the business is presented. The results should enable the potential new entrants to learn about the motives as well as the challengers and barriers for different types of remanufacturing in networks.

Peer-review under responsibility of Assembly Technology and Factory Management/Technische Universität Berlin.
doi:10.1016/j.procir.2014.07.033

2. State of the art

2.1. Remanufacturing

Several definitions for *remanufacturing* can be found in the literature, including "recycling by manufacturing 'good as new' products from used products" [2], "the process of restoring a non-functional, discarded, or traded-in product to like-new condition" [3], and "a process of returning used products to at least original performance specification from the customers' perspective and giving them warranties at least equal to that of new equivalents, is regarded as a vital strategy in waste management and environmentally conscious manufacturing" [4].

Remanufacturers have been "recycling" for more than 80 years, since the World War II when the tremendous need to reuse automotive and truck parts gave birth to the industry. Natural resources where scarce, and many of the resources available were consumed by war industry to build military vehicles [5]. The material and energy savings have therefore had a big role as an enabler for remanufacturing.

Even if remanufacturing has been performed in some form for decades it is well known only in specific industrial fields and few geographical areas. North America is the largest remanufacturing market in the world. The remanufactured products are well accepted as cheap alternatives to the new equivalents. Currently, as the awareness and interest in ecologic sustainability is growing, remanufacturing is also achieving more attention. In China, remanufacturing is still in the primary stage, but political pressure to grow in this area exists. China is the only big economy in the world that has remanufacturing in its political agenda. In Europe, the interest for remanufacturing is mainly focused on car industry, but slowly spreading to other industries. Europe has a very high intensity of Independent Aftermarket (IAM) and Original Equipment Sales (OES) aftermarket participants, but Remanufacturing is, nevertheless, not as accepted as in North America [6].

2.2. Strategic cooperation networks

In the past few decades the operations environment of production companies has dramatically changed. Today, the management has to deal with increasing turbulences of the market. The velocity of changes in customer requirements, demands and trends has increased. While the variety is increasing, the product life spans are decreasing. This ambivalence dictates the change from a fixed production to variable processes [7]. This development is even more important for the remanufacturing process as its flexibility and uncertainty is higher than in common manufacturing process. Companies are forced to be flexible and fast in order to reach their goal of a successful long-term development in the market. One strategy for small- and medium-sized enterprises (SME) to solve this problem is to operate in cooperation with other companies, creating business networks with complementary competences [8].

The idea of cooperation is to combine forces of several actors to solve tasks, while the responsibilities are shared. For good cooperation one needs good communication and coordination [9]. In these strategic networks, companies decentralize the structure of their enterprise to reach more effective material and information flows [10]. For each actor the goal is to focus on their core competencies. This increases the competiveness of the company, while increasing the dependency to other companies. To prevent the failure of commitments of the close and important partners, cooperation networks are implemented.

Economies of scale and of scope summarize the economic interest to develop strategic networks. The economies of scale describe the reduction of unit production costs while increasing the production amount. SMEs specially benefit from the integration in a network by increasing their production amount, while solely focusing on the equipment needed for their specific activities, reducing the capital needed for equipment investments [11, 12]. The economies of scope deals with a broader repartition of production costs by increasing the product diversity, in combining equipment for a whole product range instead of a single product. [7, 12]

2.3. Remanufacturing processes

Östlin [13] has divided the operation of remanufacturing network into two processes – the internal and external process to emphasize the fact that remanufacturing is more than a factory floor process. The remanufacturing system addresses both the internal processes of disassembly and reproduction and the external processes of supplying remanufactured products to customers, as well as collecting cores (used products) back from the customers.

The *internal remanufacturing process* refers to all the factory floor activities performed during the whole remanufacturing process. These activities include such as inspection, cleaning, disassembly, reprocessing, reassembly, testing and storage and can be performed by a single or multiple companies [14, 2].

The *external remanufacturing process* refers to the operative and logistics processes performed after or prior to the internal process. The forward chain concerns the flow of physical products from producer to customer, while the reverse chain describes the flow of physical products from customer to producer. These flows are then "closed" by, for example, the remanufacturing operation and can be referred as a closed-loop supply chain [15].

What really sets remanufacturing apart from manufacturing is the reverse supply chain that involves the coordination and control, physical pickup and delivery of the used material, parts and products from the customer to reprocessing. The reverse logistics chain is different form the forward supply chain in many respects. The different characteristics include:

- Unpredictable return flow of cores,
- The need for disassembly even prior to return shipment
- Needs for core inventories, management challenges
- The chain cannot be optimized e.g. for speed

2.4. Motivations and challenges for remanufacturing

The barriers for remanufacturing have been widely studied and can be summarized in three categories – collection and reverse logistics, remanufacturing operation, and market acceptance.

The relationship between remanufacturer and core supplier encloses numerous challenges. The main concerns are related to managing the uncertainties about the quality, the quantity and the time of return of the used product, also referred to as "core". The product follow-up costs during the customer possession and the core supplier selection process are also mentioned. [16, 17]

Reported in the research are also reverse logistics related challenges – the cost of core inventories, the geographical dispersion of cores, and the need for testing cores before transportation. The complete reverse logistic channels need to be structured. [16, 17, 18]

Product design also brings challenges for remanufacturing. Diverse product ranges and raw material variety with little durability hinders the standardization and cost efficiency of remanufacturing processes. The products have rarely been designed for remanufacturing; the product design is often led by aesthetics rather than functionality; and utilizes immature technologies, all resulting in major challenges for remanufacturing. [18, 19, 20, 21]

In the remanufacturing operation, remanufacturers face high cost and complexity of core testing phase as the most frequent challenge. The disassembly is complicated by product design and by the complexity and variability of the cleaning stage. The processes of remanufacturing are difficult to standardize partly due to the variability of components, parts, products and processes. Employees with multiple skills are required and need to be managed. The resources needed for overcoming these challenges hinder the value-added of remanufacturing activities. [16, 17, 18, 19, 20, 21]

The market demand is another challenge. Companies affirm facing a low or unstable demand of remanufactured products. A low customer acceptance, due to an uncertainty about the quality of remanufactured goods and a poor structure of sales channel hinder the market growth. These aspects are however only mentioned when product ownership is transferred during the sale. Hence, such innovative distribution concepts such as Product-Service-Systems are a potential solution for improved management and results. [16, 17, 18, 19, 20, 21]

The motivations for companies to perform remanufacturing are usually economic or ecologic, despite these numerous challenges. Economic motivations regroup potential cost savings in comparison with ordering new parts. These savings can be injected in higher margin levels or on the acquisition of new market segments yet not achievable with new products. The OEMs are rather reluctant to remanufacturing as they fear cannibalism of new products [22]. However, they may still perform reverse logistic operation to face the competition of independent remanufacturers. Further, some companies are interested in the feedback from returned cores when they are tested, as this information is precious for continuous improvement internal processes.

Ecologic motivations are mostly incentive by the respect of regulations extending producer responsibility beyond the product sale. Bigger companies also do carry an internal company policy toward the environment, and may present remanufacturing operation as a strategy to reduce environmental impacts of their production activities [22].

3. Research gap and methodology

Among the strategic networks there is a huge variety ranging from more stable arrangements with long-term contracts and agreements to virtual networks [23, 24], where cooperation is only project based. The main success factors of a network are common objectives, a productive distribution of tasks, the joint execution of certain business functions, and the limited economic independence of the partners. The major problems, possibly destroying the network, can be categorized as human, organization, and technology related problems [9].

There is very little research carried about the identification of network types within the remanufacturing industry. Moreover, remanufacturing potential is strongly linked to the economic potential of the activity, and networking has heavily contributed to the cost optimization in the manufacturing of new products.

This paper aims at identifying the concrete collaboration possibilities between actors from the reverse supply chain in order to identify best practices for collaboration in such an environment and eventually improve the profitability perspective of remanufacturing operations. In order to reach this aim, company networks typologies are identified through comparing both the results from DEMANET and BRAGECRIM surveys carried upon European remanufacturing companies.

First, the process for the construction of a network framework is explained. Second, the remanufacturing networks types identified during a survey using the network framework are presented. Finally, the motivations and challenges for remanufacturing are specified for main type of network identified. These results aim at preparing suggestions for improving the networking potential in the remanufacturing industry by matching company profiles according to their intrinsic motivations.

4. Company profiles within remanufacturing networks

Companies are motivated to form production networks in order to better cope with the demands of a turbulent marketplace. They seek to minimize risks, acquire greater economies of scope and scale, and to increase flexibility, which can be achieved by establishing cooperation networks and by decentralizing the structure of larger enterprises. The establishment of networks allows the entire network to overcome challenges such as the need for investment or changes in the market which a single company acting alone could not. Within a network, processes can be carried out in parallel, reducing lead time. However, the formation of networks presents several challenges, which can only be overcome through the creation of common objectives and a

high degree of cooperation between companies within the network.

4.1. Framework for remanufacturing networks

To create a framework to systematically classify the remanufacturing networks, the potential actors, their activities and processes, as well as their place within a closed-loop value chain have been defined. The actors are disassembly operations suppliers, end users, independent and contracted remanufacturers, logistic operators, raw material suppliers, recycling companies, retailers, and service providers.

As one actor can effectuate different activities, a list of the activities inside a closed-loop supply chain has been defined. The main activities are parts fabrication, product assembly, distribution and services, use, disposal, recycling, collection, inspection and separation, disassembly and cleaning, and testing. These activities have been separated according to their relevance for the manufacturing or the remanufacturing processes. The framework is depicted and presented in Fig. 1.

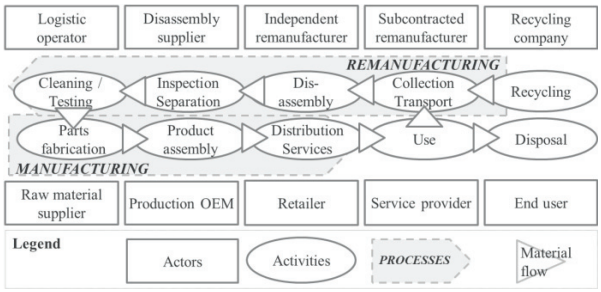

Fig. 1. Illustration of the remanufacturing network framework

4.2. Remanufacturing networks typology

In order to observe how remanufacturing companies network together, a survey aiming at identifying the different actors within remanufacturing networks had been carried out during the REMATEC Exhibition, held in Amsterdam in June 2013. Additionally, remanufacturing companies from Finland brought their contribution through an online version of the survey. A total of 84 companies indicated what their partnership structure looks like. Most of the companies, predominantly SMEs, reside in Germany, Netherlands, Finland, UK or Italy and operate on automotive or industrial machinery industries. Three types of networks (see Table 1) were identified:

- Networks where remanufacturing is integrated in OEM processes. The OEM uses its own resources for the execution of the remanufacturing process but may work with other actors for secondary processes.
- Networks where remanufacturing is done by an OEM subcontractor: The subcontracted company interfaces between supplier-producer and producer-customer; subcontracting may be used to gain access to additional production capacity or to gain access to a specific technology or competence.
- Networks where remanufacturing is done by independent remanufacturers, shows the case of remanufacturing companies working without contractual arrangements with OEM. The independent remanufacturer becomes a direct competitor of the OEM.

Table 1. The types of remanufacturing networks.

Type	Description	Frequency
Case A: OEM-controlled processes		*45,56%*
A1	Full OEM-operated remanufacturing	24,05%
A2	OEM-controlled with retailer as distribution and reverse logistics operator	13,92%
A3	OEM-controlled with independent reverse logistics operators	7,59%
Case B: Remanufacturing done by contracted remanufacturers		*36,71%*
B1	Full subcontractor-operated remanufacturing	16,46%
B2	Subcontractor-controlled with independent distribution	8,86%
B3	Subcontractor-controlled with independent reverse logistics operators	6,33%
B4	Subcontractor-controlled with independent distribution and reverse logistics operators	5,06%
Case C: Remanufacturing done by independent remanufacturers		*17,73%*
C1	Full independent-controlled remanufacturing	10,13%
C2	Independent-controlled with different reverse logistics operators	5,07%
C3	Independent-controlled with different distribution and reverse logistics operators	2,53%

An example of a network typology using the framework described in Fig.1 has been presented in Fig. 2.

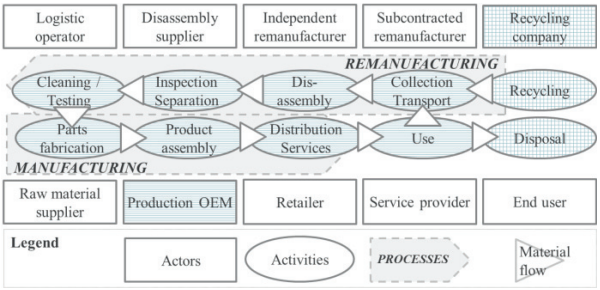

Fig. 2. Illustration of the remanufacturing network A1

4.3. Challenges and barriers for remanufacturing

Based on the survey results, the biggest general challenges for remanufacturing (see Fig. 3) come from the acquisitions and collection of cores (the used end of life products). The Independent Remanufacturers (IR) see this less of a problem than the Original (OEM) or Contracted Remanufacturers (CR). The other main challenges for OEMs are related to costs of remanufacturing and the effect on new product sales. The original manufacturing process and product specifications are available so the remanufacturing process is not a major issue. The OEM contracted remanufacturers generally have the same challenges as OEMs, but there are some interesting

differences – the core collection is seen as a much bigger problem, along with the complexity of the remanufacturing process. The biggest challenges of IRs are related to the complexity of the remanufacturing process and unpredictable or low demand. Core collection and demand are seen as equally important challenges.

The other challenges are related to the requirements or approvals by the authorities or other official bodies; specific core collection problems (size or location) or spare part availability; general customer acceptance, quality of the product or cheap alternatives; getting started in remanufacturing, technical or market knowledge, or resources and process capabilities.

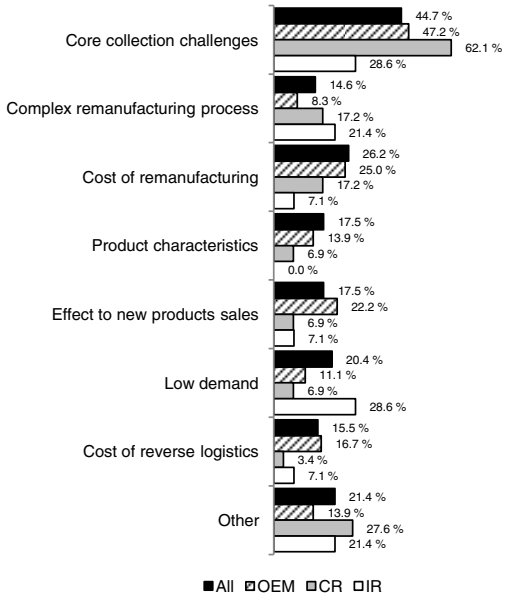

Fig. 3. Greatest challenges and barriers for remanufacturing.

4.4. Objects and motivations for remanufacturing

The remanufacturing activities are primarily motivated by profitability or growth (see Fig. 4), applying for OEMs, CRs, as well as IRs. Existing demand for remanufactured products is important to all types of remanufacturers, especially CRs. Demand and profit naturally correlate – there would be no remanufacturing if there were no demand for it. Environmental issues are much more important to OEMs than other types of remanufacturers. OEMs are typically larger companies that have brand and responsibility issues that they need to respond to. For CRs and IRs the environmental aspects of remanufacturing are simply a "side effect".

Contrary to general assumptions the legislation seems to have practically no motivating effect on companies. The main motivation comes from profitability and growth of the business with slight effect from rising costs of raw materials.

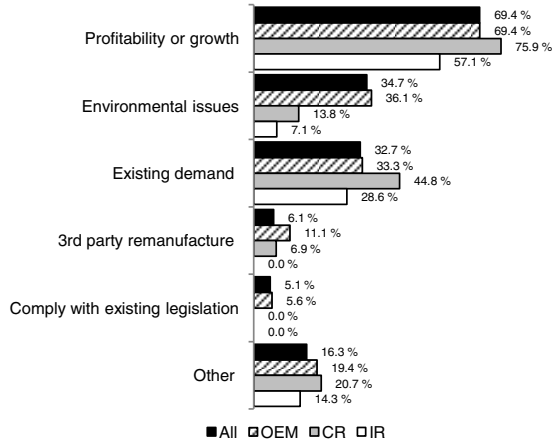

Fig. 4. Most important motivating factors for remanufacturing.

5. Discussion

This survey brought insight in how could remanufacturing networks be classified according to the distribution of activities to different actors. First of all, it is important to notice that the OEM has an effective control on 82.27% of the remanufacturing processes surveyed, for both integrated and outsourced processes. The second major teaching of network classification is that the distribution and reverse logistics activities are the only activities outsourced to specialized companies. The remanufacturing process itself is always operated by only one actor that can be an OEM, a contracted or an independent remanufacturer.

The implementation of remanufacturing networks has the potential to provide many benefits to companies involved in such networks, primarily through improved production flexibility, lower risks, and better economies of speed and scale – the better possibilities to deal with the high product variation present in remanufacturing. Two factors may change this situation. First, the growth of the remanufacturing industry, and secondly, a more balanced core supply. These factors would allow bigger lot sizes and volume of standardized cores, which allows better economies of scale and decreases transaction costs, improving power of remanufacturing networks.

The power of the network is dependent on the number of independent actors within it, which is dictated by the transaction costs of the network. These costs are influenced by specificity, uncertainty, and frequency of cooperation within the network. As a result of the labor-intensive nature of the industry, human specificity is high. There is also high uncertainty, and low frequency, all of which represent major barriers to the implementation of production networks.

By far the greatest motivation for remanufacturing comes from profitability and growth. In some cases remanufacturing is highly profitable business, mostly due to vast material savings. Remanufacturing is also seen as prominent replacement for traditional manufacturing that has left Europe to lower labour cost countries.

Environmental issues were seen as the second important motive for remanufacturing, especially for OEMs. These are

concerned about the future material supply and scarcity, and want to decrease material usage and minimize waste. The results, however, indicate that the environmental legislation is not an important motive for remanufacturing. This has been also stated by previous studies. A reason for that might be that remanufacturing is not included in the terms of legislation, e.g. the ELV directive [26] does not include remanufacturing. Including remanufacturing to the calculation method of ELV directive would maybe motivate the manufacturers learn remanufacturing and accept it as a one form recycling.

Core collection was seen as the greatest challenge, which again has been indicated by previous studies. What is interesting is that the independent remanufactures perceive it as far less a problem. This may be result of company size and market geography, IRs are mostly small and predominantly local operators.

6. Conclusions

Remanufacturing is not well known or accepted in Europe. Remanufactured products are considered to be equal to a new equivalent when considering the quality and given warranties. But it is still important to notice that almost as many respondents see the remanufactured products to be inferior to newly manufactured equivalents.

Today, In Europe, remanufacturing is mainly utilized by the automotive industry, but the interest is slowly spreading to other industries. According to the survey presented in this paper, remanufacturing in Europe is typically integrated in OEM processes or done by OEM contracted remanufacturers. The most important motivating factors for them were profitability or growth, or existing demand. The greatest challenges were in core collection.

Acknowledgements

This paper is based on the results of two research projects. The Brazilian-German Collaborative Research Initiative on Manufacturing Technology - BRAGECRIM - a framework program to fund and support collaborative projects between German and Brazilian research groups in the field of advanced manufacturing technologies. Dematerialization and sustainable competitiveness through New Models for Industrial Networking - DEMANET – the research project performed in Finnish Green Growth Technology Program funded by the Finnish Funding Agency for Technology and Innovation - Tekes - and VTT Technical Research Centre of Finland.

References

[1] Ellen MacArthur Foundation. Towards a circular economy. Economic and business rationale for an accelerated transition. 2012. 98 pp.
[2] Steinhilper R. Remanufacturing – The ultimate form of recycling. Fraunhofer IP Vertag. 1998.
[3] Lund RT, Houser WM. Remanufacturing – An American perspective. 5th International Conference on Responsive Manufacturing - Green Manufacturing. Ningbo China, 11-13 Jan 2010.
[4] Ijomah WL. Editorial, Journal of remanufacturing. 2011:4.
[5] APRA webpage. Online at http://www.apra.org/about/Reman.asp. Visited 23.4.2014.
[6] Bücker C. A SME view to the remanufacturing business trends, challenges & critical impacts. Reman Summit 2012, Bayreuth, 2012.
[7] Westkaempfer E. Die Wandlungsfähigkeit von Unternehmen. Fraunhofer IPA-Innovationsforum. 1998. p. 131-140.
[8] Martin J. Logistics and Supply Chain Management - Strategies for Reducing Costs and Improving Services. London: Pitman Publishing. 1992.
[9] Luczak H, Eversheim W. Telekooperation. Industrielle Anwendungen in der Produktentwicklung. Berlin: Springer Verlag. 1999.
[10] Zheng L, Possel-Dölken F. Strategic Production Networks. Berlin/Heidelberg: Springer Verlag. 2002.
[11] Eversheim W. Organisation in der Produktionstechnik, Band 3. Berlin: Springer Verlag. 1997.
[12] Wrede V. Grundlagen des Supply Chain Managements. Aachen: Ed.: Luczak H.; Eversheim W. 1999.
[13] Östlin J. On Remanufacturing Systems - Analysing and Managing Material Flows and Remanufacturing Processes, Linköping Studies in Science and Technology, Thesis No. 1192 Department of Mechanical Engineering, Linköping University, SE-581 83 Linköping, Sweden. 2008.
[14] Sundin E. Product and Process Design for Successful Remanufacturing", in Production Systems, Dissertation No. 906, Department of Mechanical Engineering. Linköping University. Linköping, Sweden.2004.
[15] Krikke H, le Blanc I, van de Velde S. "Product modularity and the Design of Closed-Loop Supply Chain", Californian Management Review, 46/2. 2004. p. 23-39.
[16] Jacobsson N. Emerging Product Strategies: Selling services of remanufactured products. Master. The International Institute of Industrial Environmental Economics – Lund University, Sweden, 2000.
[17] King AM, Burguess SC. The development of a remanufacturing platform design: a strategic response to the Directive on Waste Electrical and Electronic Equipment. Proc. IMechE Part B: Journal of Engineering Manufacture, 219. 2005. p.623 – 631.
[18] Barker S, King A. Organizing Reuse: Managing the Process of Design For Remanufacture (DFR). POMS 18th Annual Conference Dallas, Texas, EUA. 2007.
[19] Amezquita T, Hammond R, Salazar M, Bras B. Characterizing the remanufacturability of engineering systems. Proceedings of ASME Advances in Design Automation Conference, Boston, Massachusetts, 82, 1995, p. 271-278.
[20] Ijomah WL, McMahon CA, Hammond GP, Newman, ST. Development of design for remanufacturing guidelines to support sustainable manufacturing. Robotics and Computer-Integrated Manufacturing. Vol 23-6. 2007. p. 712–719
[21] Giuntini R, Gaudette K. Remanufacturing: The next great opportunity for boosting US productivity. Business Horizons, 2003.
[22] Matsumoto M, Yasushi U. An analysis of remanufacturing practices in Japan. Journal of Remanufacturing 1-11. 2011.
[24] Kürümlüoglu M, Nostdal R, Karvonen I. Base concepts, in Camarinha-Matos, L., Afsarmanesh, H., Ollus, M. (eds.), Virtual organizations. Systems and Practices, Springer-Verlag. 2005. pp. 11-28
[25] Camarinha-Matos LM, Afsarmanesh H, Ollus M (eds.). Methods and tools for Collaborative Networked Organizations. ISBN 978-0-387-79423-5. Springer, New York. 2008
[26] ISO 22628:2002. ELV Road vehicles-Recyclability and recoverability calculation method.